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AERODYNAMIC CHARACTERISTICS IN PITCH OF SEVERAL MODELS OF THE APOLLO ABORT SYSTEM FROM MACH 1.57 TO 2.16 (U)

by Roger H. Fournier and William A. Corlett

*Langley Research Center
Langley Station, Hampton, Va.*

[redacted]

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AERODYNAMIC CHARACTERISTICS IN PITCH OF SEVERAL MODELS OF THE APOLLO ABORT SYSTEM FROM MACH 1.57 TO 2.16*

By Roger H. Fournier and William A. Corlett

SUMMARY

An investigation has been conducted to determine the aerodynamic characteristics in pitch of several models of the Apollo spacecraft abort system. The investigation was performed at Mach numbers from 1.57 to 2.16, at angles of attack from -9° to 19° at zero sideslip, and at Reynolds numbers per foot from 2.0×10^{6} to 3.5×10^{6}. No analysis of the data is presented in this report.

INTRODUCTION

The National Aeronautics and Space Administration has the responsibility of placing a man on the moon in this decade, and in support of this mission, numerous wind-tunnel investigations of configurations - varying from launch vehicles to spacecraft components - have been initiated at various NASA facilities. As a part of this program, the abort system which is a pilot-safety feature must be studied to determine whether it is aerodynamically suitable for the mission. The abort system is composed of the Apollo spacecraft in combination with a rocket-tower attachment.

Previous investigations of the abort configuration have indicated erratic stability characteristics apparently resulting from unsteady separated flow conditions induced by the escape-tower arrangement. (See refs. 1 to 5.) In an effort to eliminate these unsteady flow conditions, various arrangements of tower fairings, rocket-nozzle shrouds, and flow stabilizing devices (on tower only) have been considered.

Studies of several of these abort systems were performed in the Unitary Plan wind tunnel of the Langley Research Center at Mach numbers from 1.57 to 2.16 and the results of these studies are presented herein without analysis.

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*Title, Unclassified.

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SYMBOLS

The coefficients of forces and moments are referred to the body-axis system and the moments were referred to locations shown in figure 1. Symbols are defined as follows:

C_A	axial-force coefficient, $\frac{\text{Axial force}}{qA}$
C_N	normal-force coefficient, $\frac{\text{Normal force}}{qA}$
C_m	pitching-moment coefficient, $\frac{\text{Pitching moment}}{qAd}$
d	maximum diameter, 10.920 and 4.50 in.
M	Mach number
q	free-stream dynamic pressure, lb/sq ft
A	maximum cross-sectional area, 0.6504 and 0.1104 sq ft
α	angle of attack referred to model center line, deg
p_t	free-stream stagnation pressure, lb/sq in.
T_t	stagnation temperature, $^{\circ}$F

APPARATUS AND METHODS

Wind Tunnel

Studies were conducted in the low Mach number test section of the Langley Unitary Plan wind tunnel which is a variable-pressure, continuous-flow tunnel. The test section is approximately 4 feet square and 7 feet long. The nozzle leading to the test section is of the asymmetric sliding-block type which permits a continuous variation in test-section Mach number from about 1.5 to 2.9.

Models

Dimensional details of the configuration are presented in figure 1, and photographs of three of the models are shown in figure 2.

Three basic models were used for this sequence of tests: an 0.070-scale model with a 35° half-cone-angle Apollo spacecraft, an 0.06825-scale model with a 33° half-cone-angle Apollo spacecraft, and a 0.020-scale model with a 33° half-cone-angle Apollo spacecraft. The 0.070-scale model was tested with a tripod tower and conical shroud fairing over the rocket nozzles, with a faired tower (no skirt fairing), and with a faired tower and the conical shroud fairing over the rocket nozzles. The 0.06825-scale model was tested with both tripod and solid towers, conical fairing over the rocket nozzles, and two and three stabilizing rings. The 0.020-scale model was tested with a four-legged tower in combination with the conical fairing shroud over the rocket nozzles.

Test Conditions

Studies were made at the following conditions:

M	p_t	T_t	R/ft
0.070-scale model			
1.57	13.0	125	3.51×10^6
1.80	14.0	125	3.50
2.16	16.5	125	3.33
0.06825-scale model			
1.57	7.0	125	1.89×10^6
1.80	8.0	125	1.99
2.16	10.0	125	2.14
0.020-scale model			
1.57	13.1	125	3.53×10^6
1.80	14.2	125	3.55
2.16	16.6	125	3.55

The dewpoint, measured at stagnation pressure, was maintained below -30° F to assure negligible condensation effects. The angle of attack was varied from approximately -9° to 19°. All studies were performed with natural transition on the models.

The aerodynamic forces and moments were measured by means of an internally mounted strain-gage balance which was, in turn, rigidly fastened to the tunnel support system.

Schlieren photographs were taken of many of the configurations and typical photographs at $\alpha \approx 0^\circ$ and $M = 2.16$ are shown in figure 3.

Corrections and Accuracies

All angles of attack have been corrected for flow angularity and structural deflection of the sting-balance combination due to the aerodynamic loads. The axial-force and drag coefficients presented are the total value of the forces measured by the balance. The pressure acting at the base of the model was not measured during the tests, and the axial forces and drag forces have not been adjusted in any way for base pressures. The sting diameter as compared to the model base diameter is small; therefore, the sting diameter has negligible effect on the base pressure of the model. The maximum deviation of the Mach number in the region of the tunnel occupied by the model is ±0.015. The estimated accuracy of the results based on the balance calibration and the repeatability of the data, are within the following limits:

α	±0.10
C_N	±0.025
C_A	±0.010
C_m	±0.022

PRESENTATION OF RESULTS

The results of the investigation are presented in the figures as follows:

	Figure
Aerodynamic characteristics in pitch of a 35° half-cone-angle Apollo spacecraft abort system:	
Tripod tower and nozzle fairing	4(a)
Faired tripod tower and nozzle fairing	4(b)
Faired tripod tower	4(c)
Aerodynamic characteristics in pitch of a 33° half-cone-angle Apollo spacecraft abort system:	
Tripod tower and nozzle fairing	5(a)
Tripod tower	5(b)
Solid tower and nozzle fairing	5(c)
Solid tower	5(d)
Tripod tower and two stabilizing rings	5(e)
Tripod tower, two stabilizing rings, and nozzle fairing	5(f)
Tripod tower and three stabilizing rings	5(g)
Tripod tower, three stabilizing rings, and nozzle fairing	5(h)
Four-legged tower and nozzle fairing	5(i)

CONCLUDING REMARKS

An investigation has been conducted to determine the aerodynamic characteristics in pitch of several models of the Apollo spacecraft abort system. The investigation was performed at Mach numbers from 1.57 to 2.16, at angles of attack

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from -9° to 19° at zero sideslip, and at Reynolds numbers per foot from 2.0×10^6 to 3.5×10^6. No analysis of the data is presented in this report.

Langley Research Center,
National Aeronautics and Space Administration,
Langley Station, Hampton, Va., November 1, 1963.

REFERENCES

1. Pearson, Albin O.: Wind-Tunnel Investigation of the Static Longitudinal Aerodynamic Characteristics of Models of Reentry and Atmospheric-Abort Configurations of a Proposed Apollo Spacecraft at Mach Numbers From 0.30 to 1.20. NASA TM X-604, 1961.

2. Morgan, James R. and Fournier, Roger H.: Static Longitudinal Aerodynamic Characteristics of a 0.07-Scale Model of a Proposed Apollo Spacecraft at Mach Numbers From 1.57 to 4.65. NASA TM X-603, 1961.

3. Pearson, Albin O.: Wind-Tunnel Investigation of the Static Longitudinal Aerodynamic Characteristics of a Modified Model of a Proposed Apollo Atmospheric-Abort Configuration at Mach Numbers From 0.30 to 1.20. NASA TM X-686, 1962.

4. Morgan, James R. and Fournier, Roger H.: Static Longitudinal Aerodynamic Characteristics of a Model of a Two-Stage Version of a Saturn Launch Vehicle With a Proposed Apollo Payload at Mach Numbers From 1.57 to 2.87. NASA TM X-602, 1961.

5. Fournier, Roger H.: Static Longitudinal Aerodynamic Characteristics of a 0.028-Scale Model of a Proposed Little Joe-Apollo Space Vehicle at Mach Numbers From 1.50 to 2.16. NASA TM X-730, 1962.

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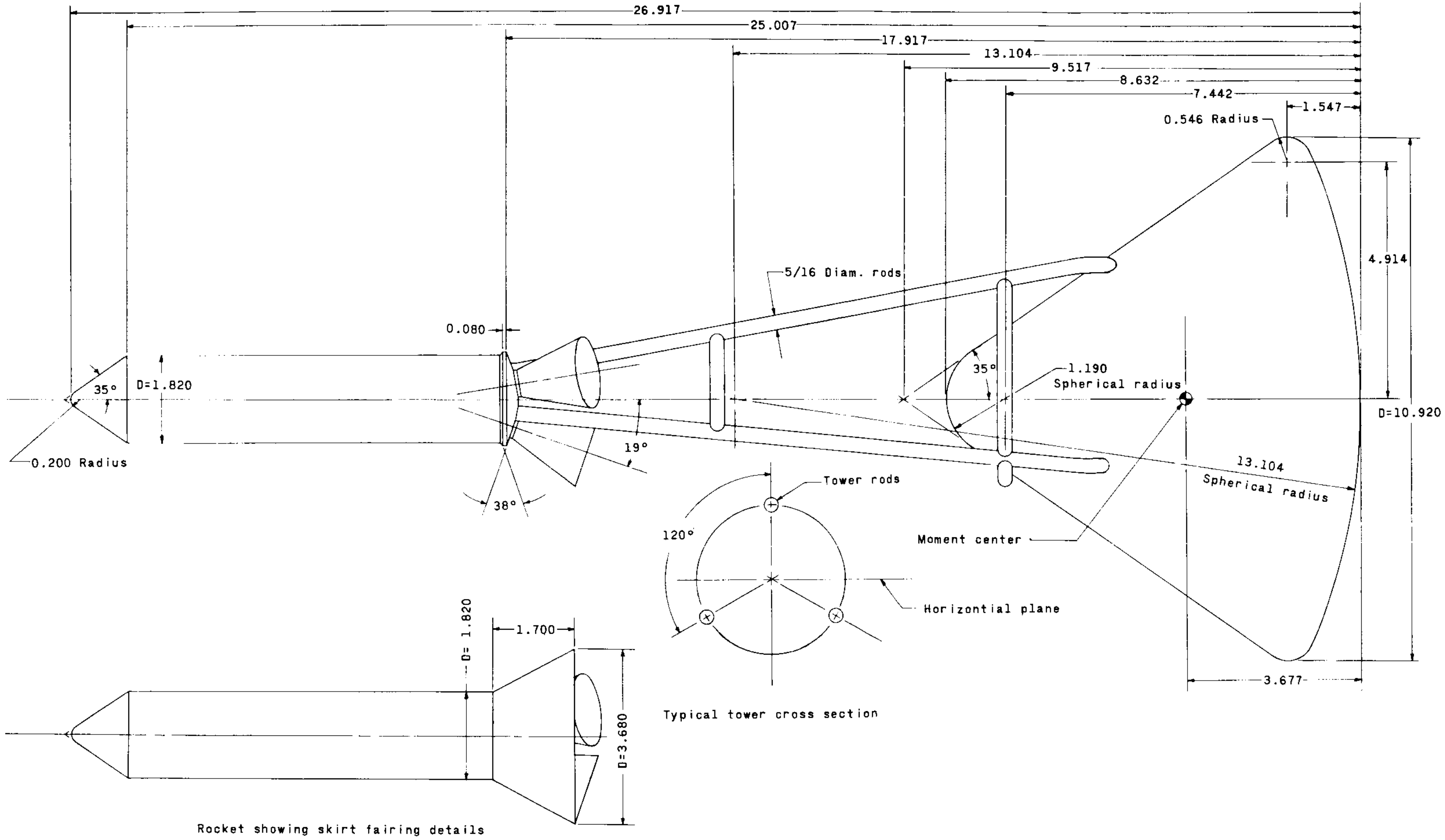

(a) 35° half-cone-angle Apollo spacecraft with tripod tower.

Figure 1.- Details of model. Dimensions are in inches.

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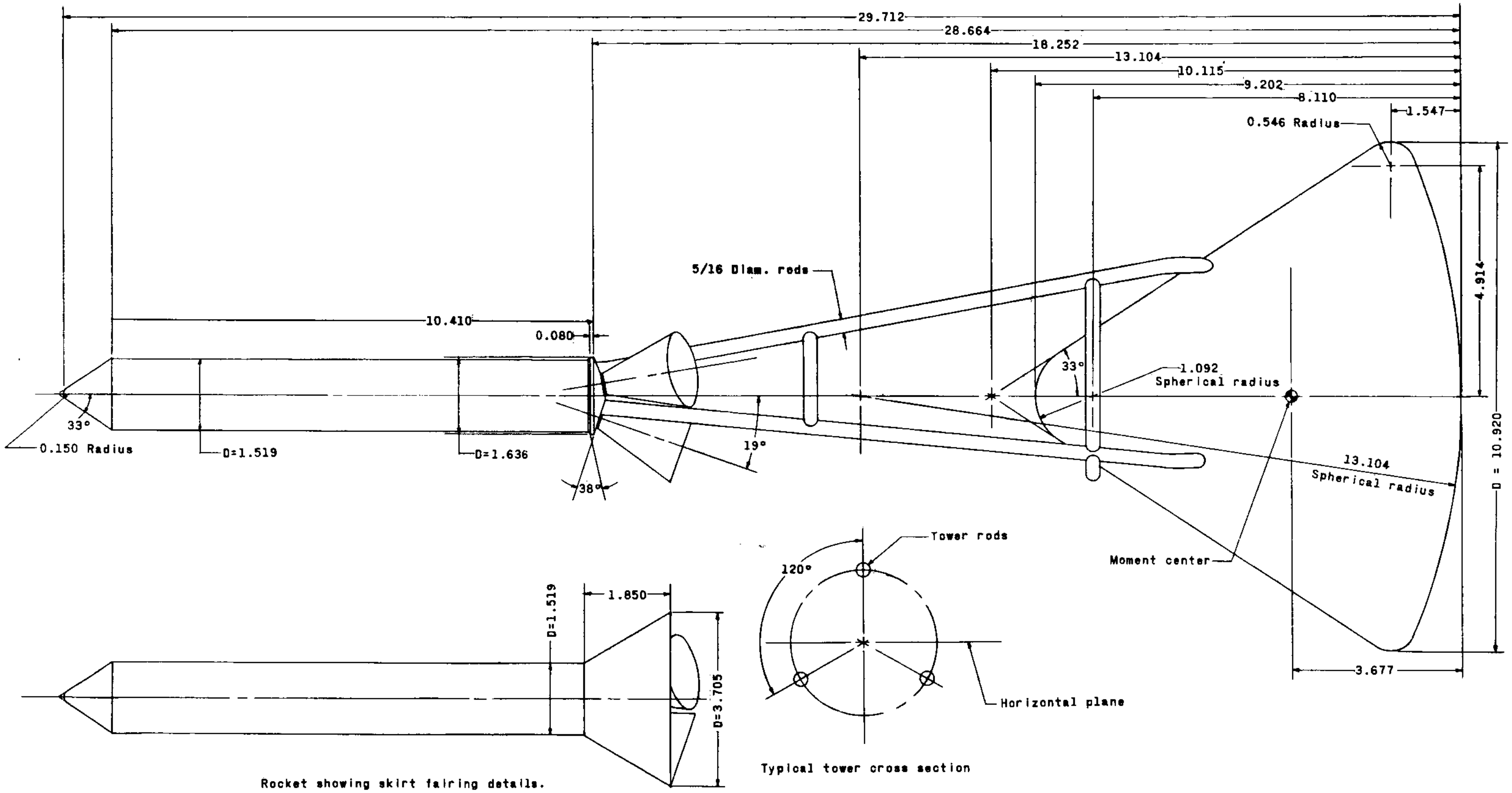
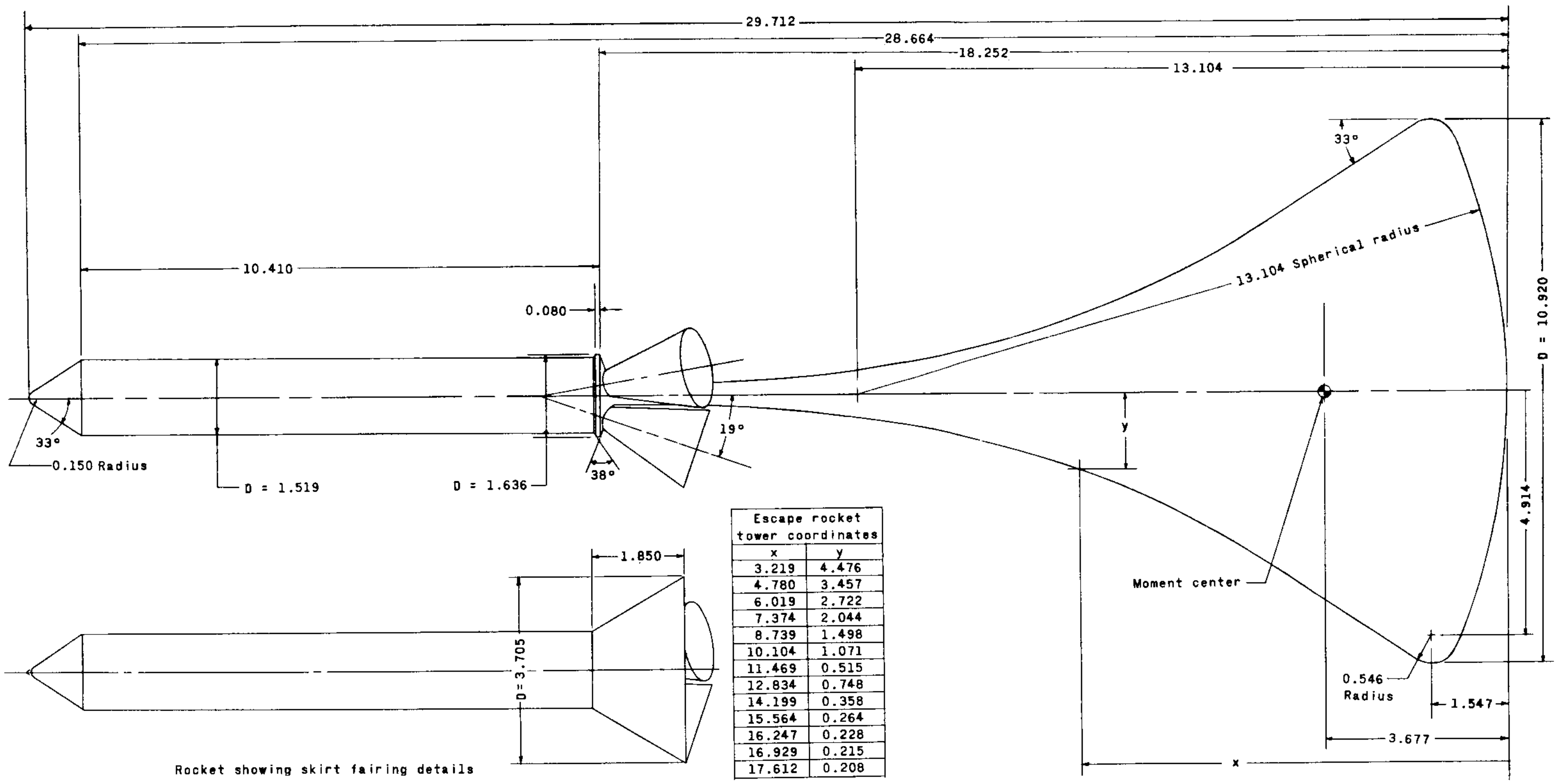


(b) 33° half-cone-angle Apollo spacecraft with tripod tower.

Figure 1.- Continued.



Escape rocket tower coordinates	
x	y
3.219	4.476
4.780	3.457
6.019	2.722
7.374	2.044
8.739	1.498
10.104	1.071
11.469	0.515
12.834	0.748
14.199	0.358
15.564	0.264
16.247	0.228
16.929	0.215
17.612	0.208

(c) 33° half-cone-angle Apollo spacecraft with solid tower.

Figure 1.- Continued.

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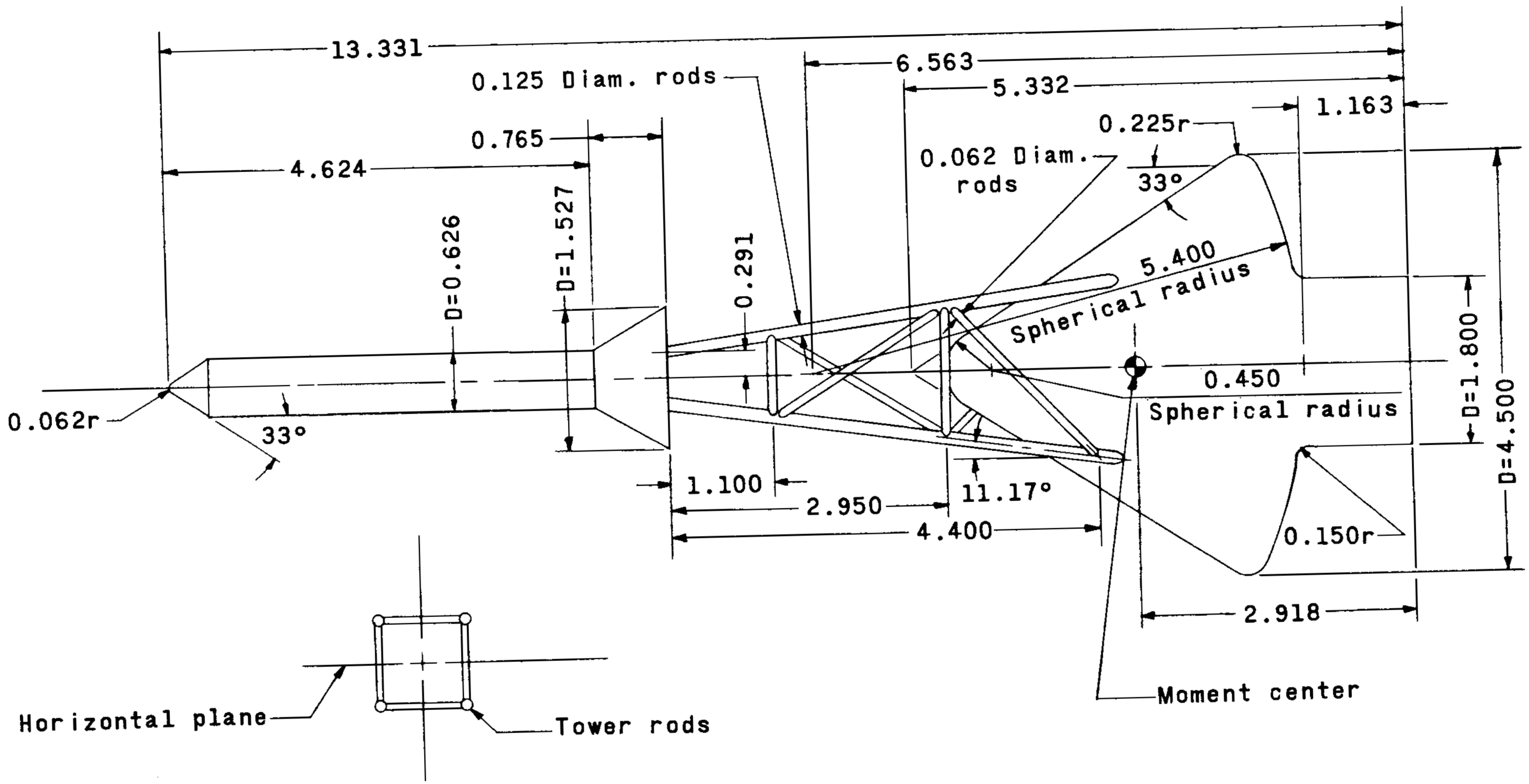

(d) 33° half-cone-angle Apollo spacecraft with four-legged tower.

Figure 1.- Continued.

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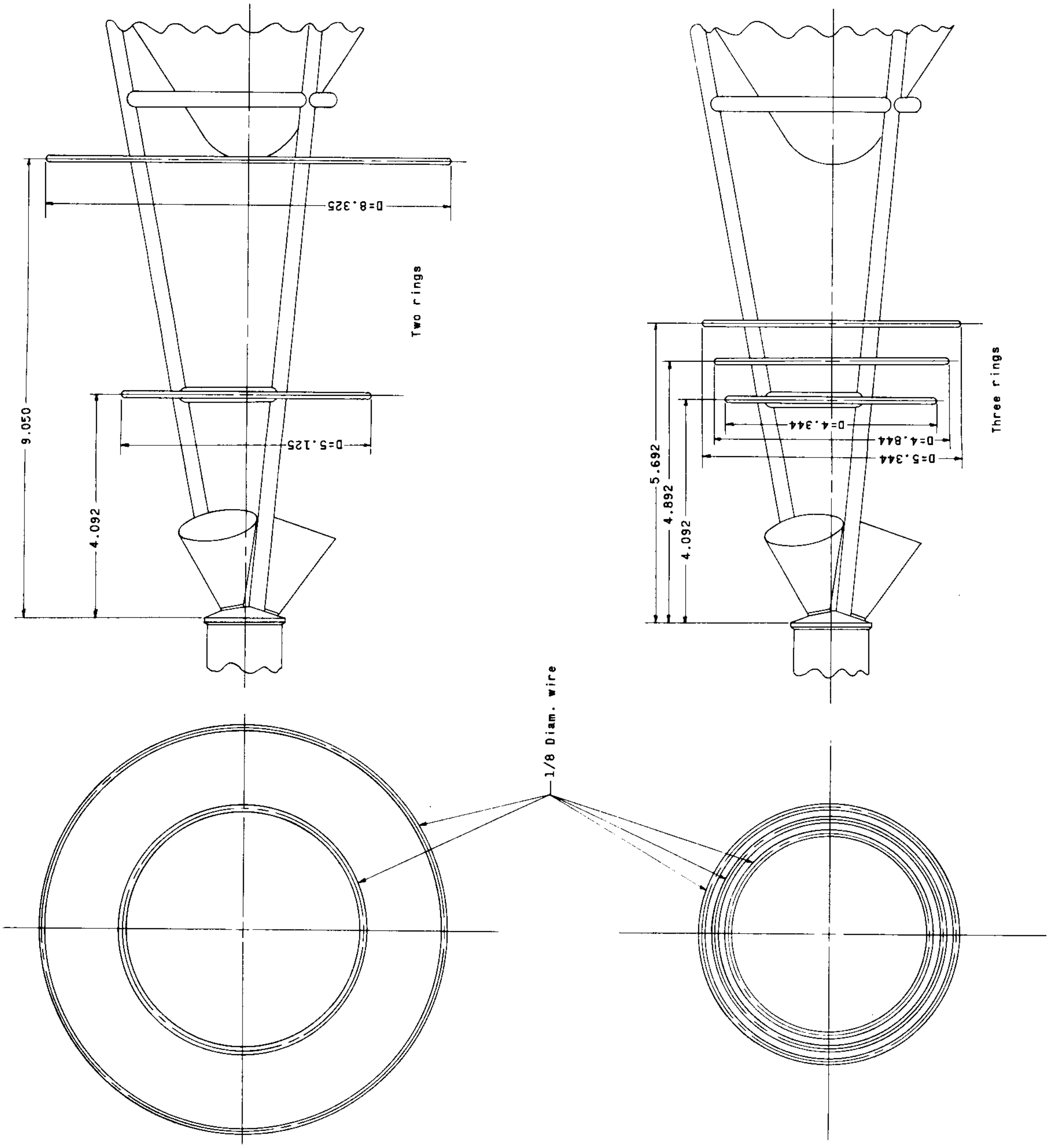
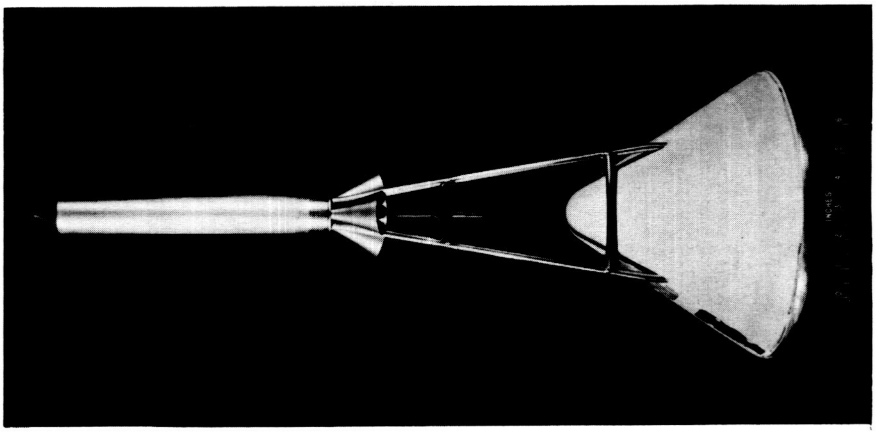
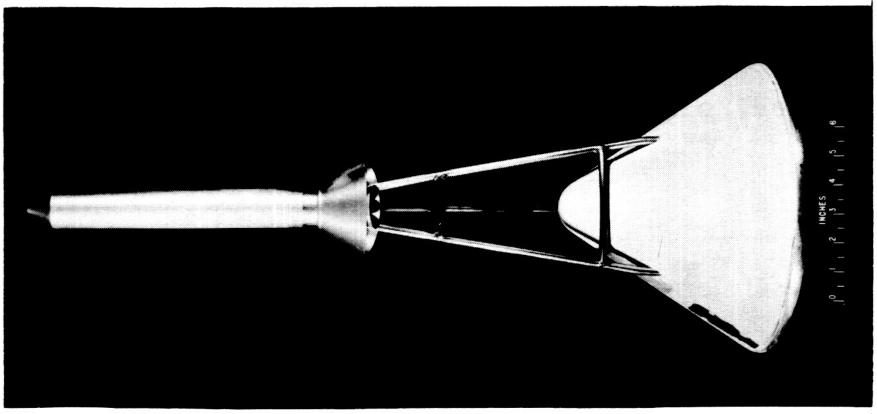


(e) Details of flow stabilizing rings.

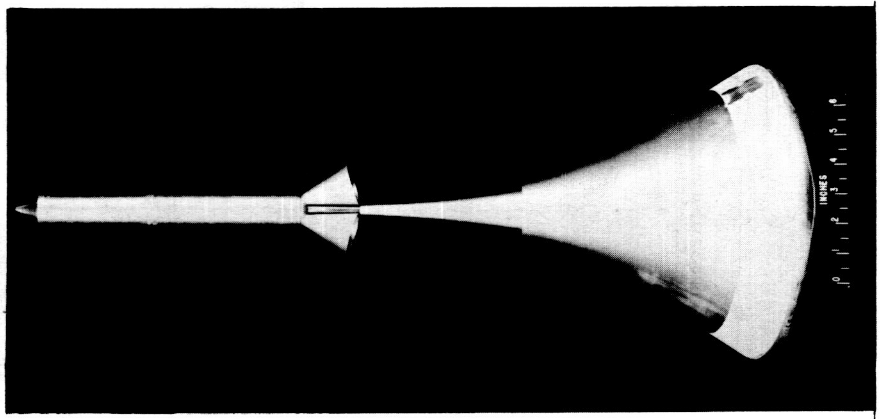
Figure 1.- Concluded.



Open tower,unfaired nozzles

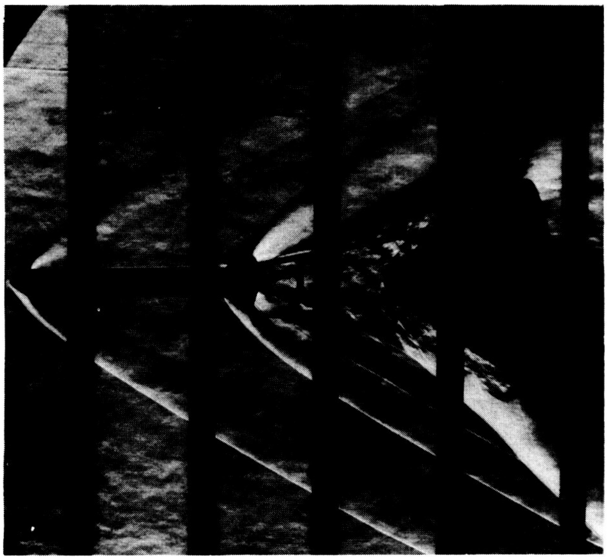


Open tower,faired nozzles



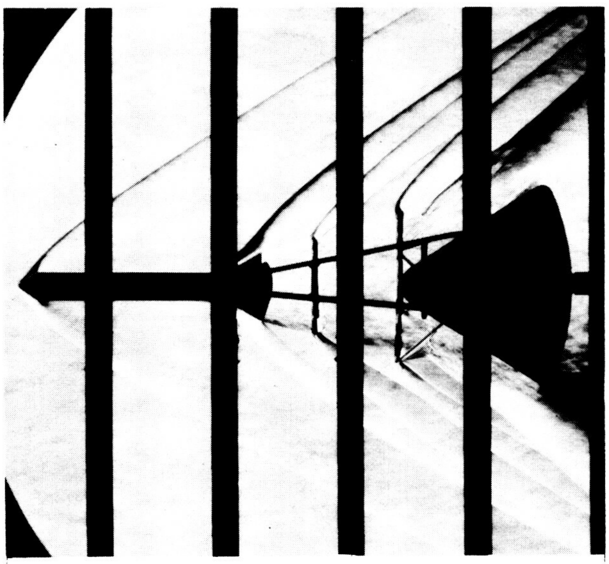
Solid tower,unfaired nozzles

Figure 2.- Photographs of three configurations tested. L-63-9244



Open tower,unfaired nozzles

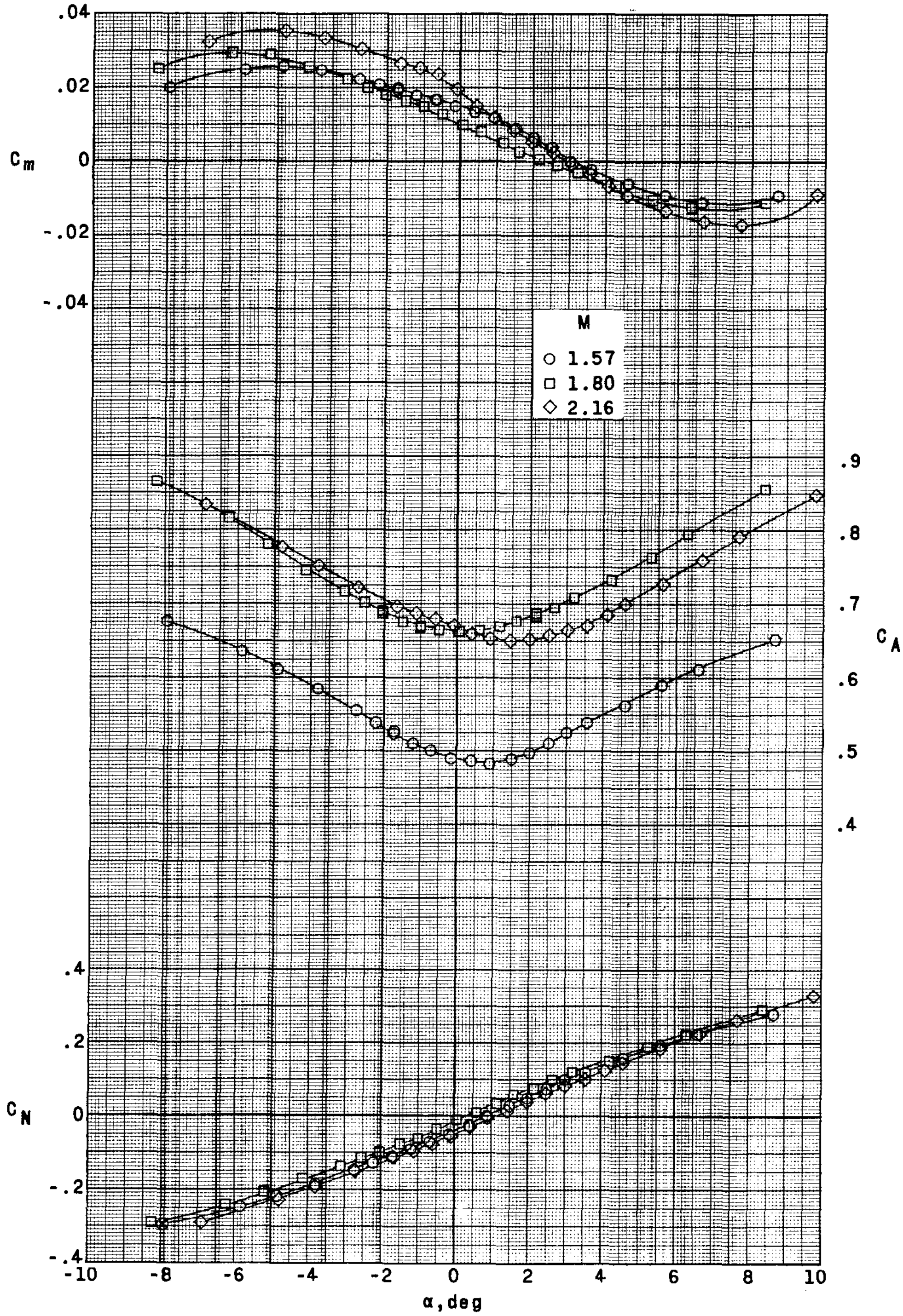
Open tower,faired nozzles



Open tower,faired nozzles,two stabilizing rings

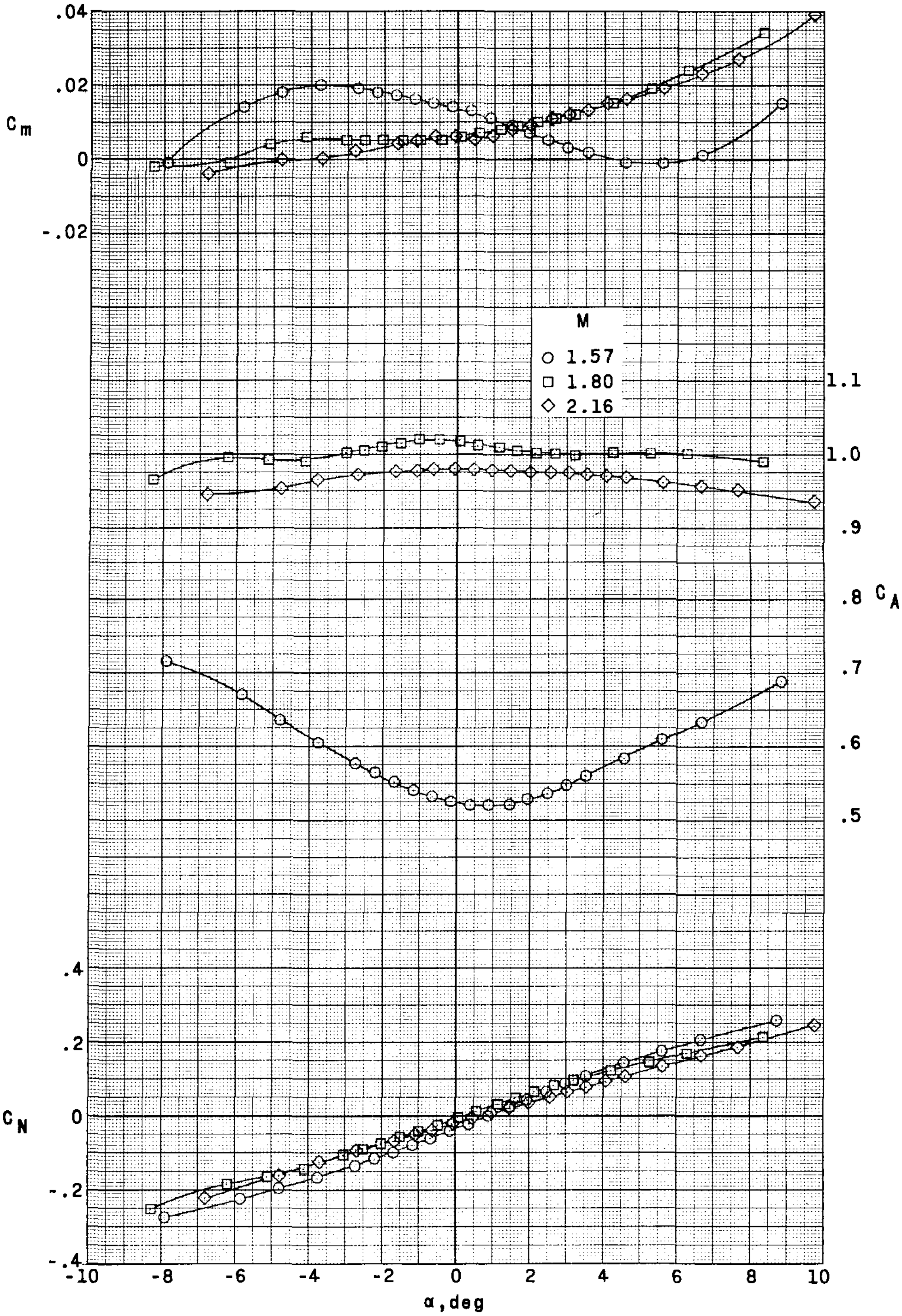
Solid tower,faired nozzles

Figure 3.- Typical schlieren photographs of 33° Apollo spacecraft. $M = 2.16$, $\alpha \approx 0°$. L-63-9245



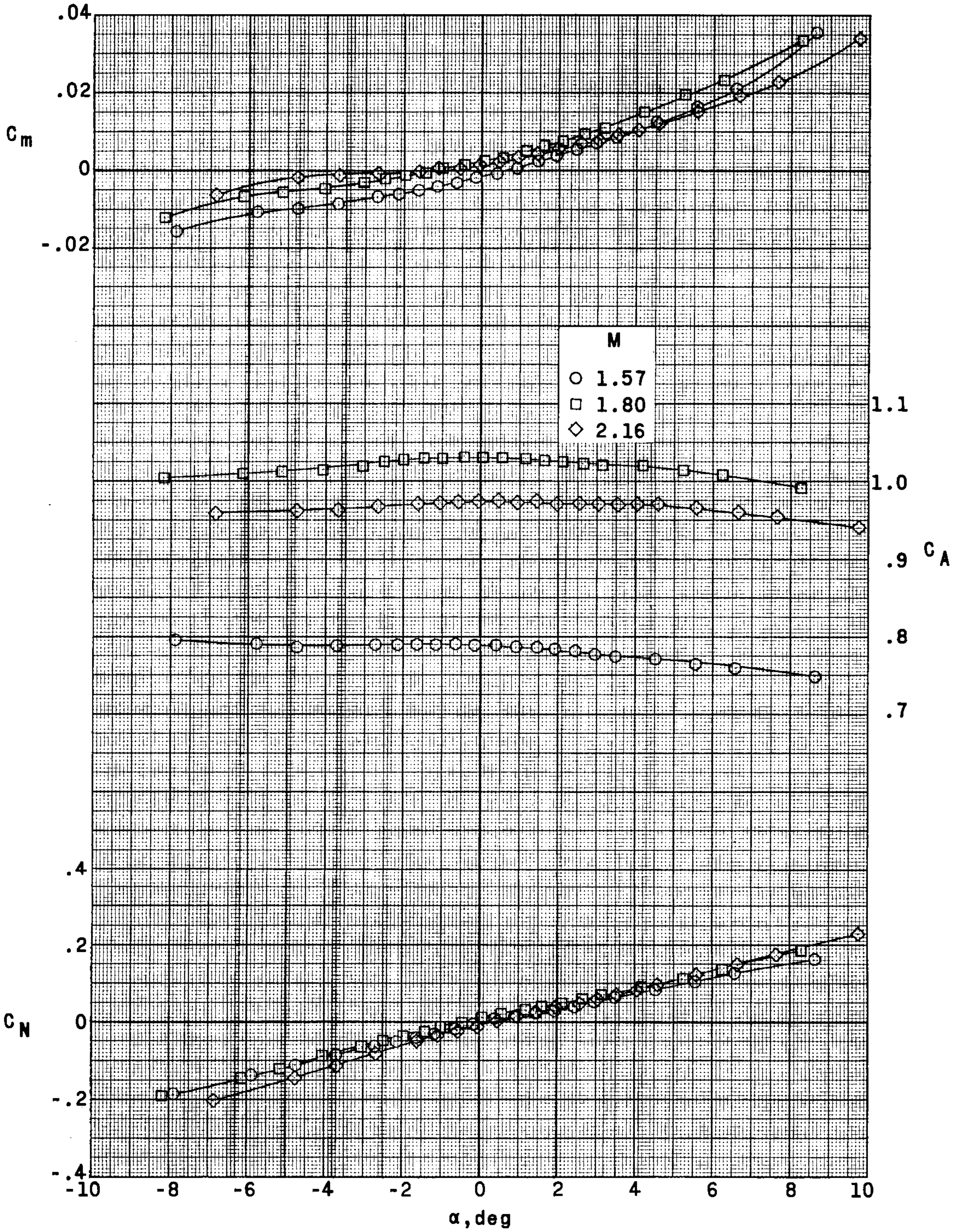
(a) Tripod tower and nozzle fairing.

Figure 4.- Aerodynamic characteristics in pitch of a 35° half-cone-angle Apollo spacecraft abort system.



(b) Faired tripod tower and nozzle fairing.

Figure 4.- Continued.



(c) Faired tripod tower.

Figure 4.- Concluded.

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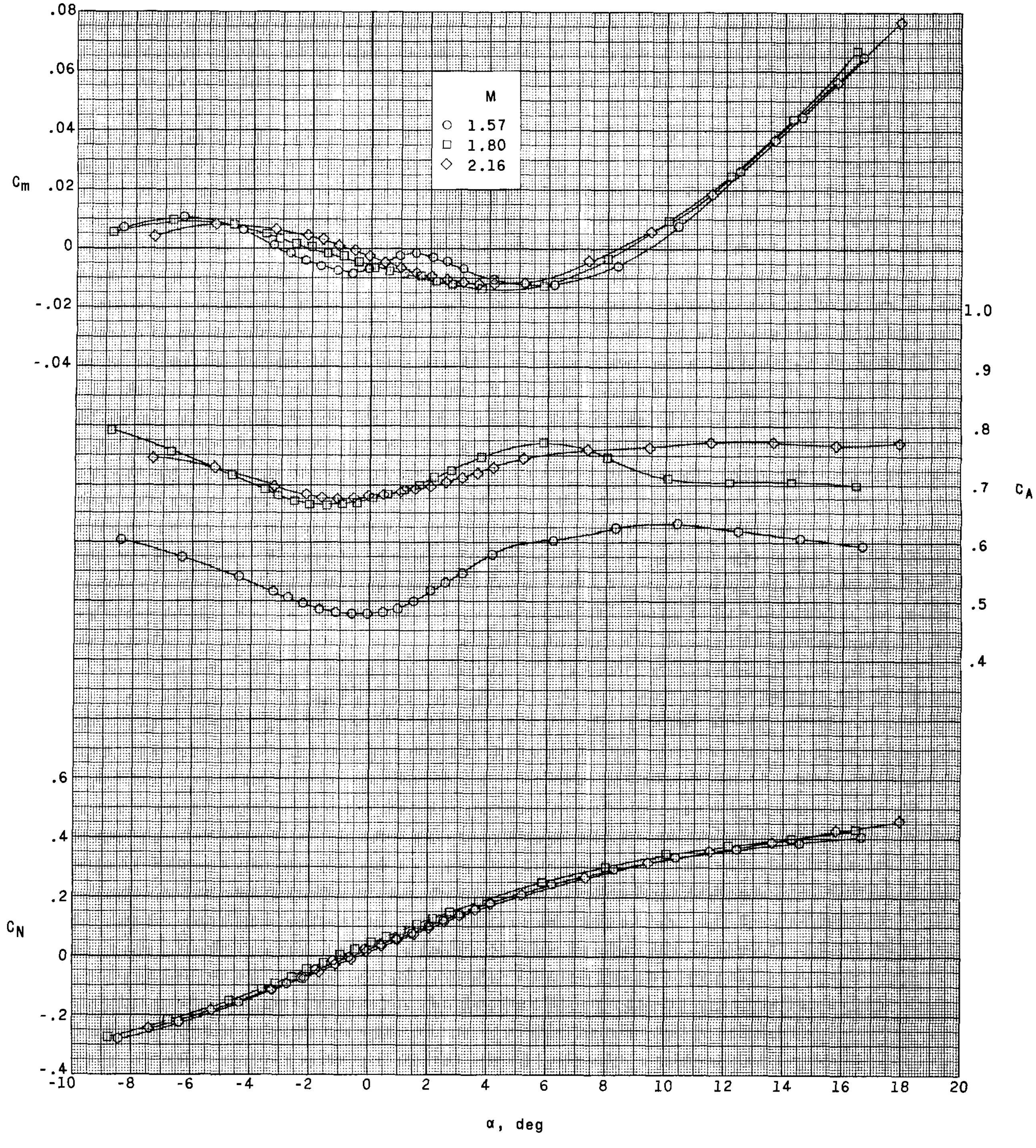

(a) Tripod tower and nozzle fairing.

Figure 5.- Aerodynamic characteristics in pitch of a 33° half-cone-angle Apollo spacecraft abort system.

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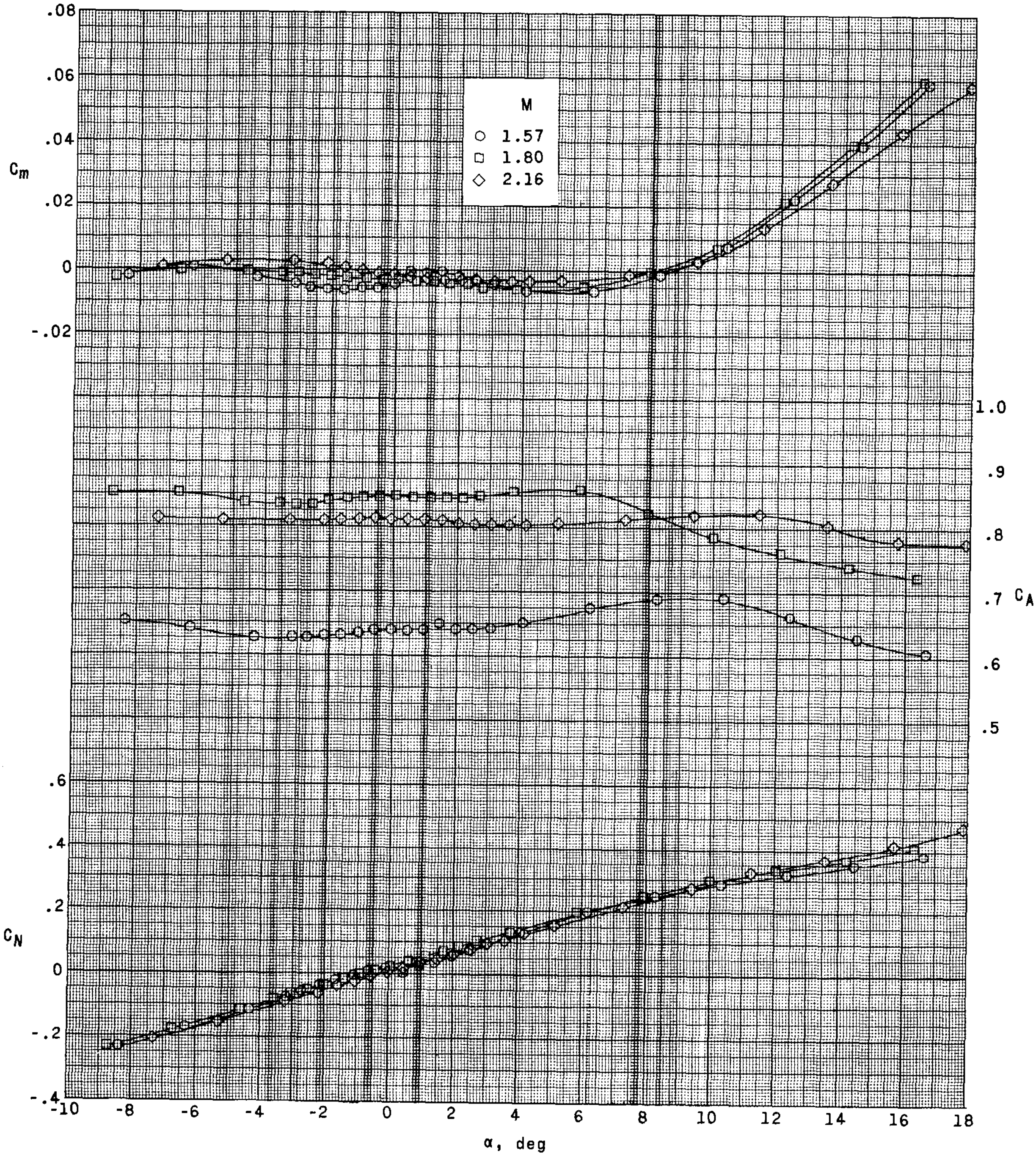
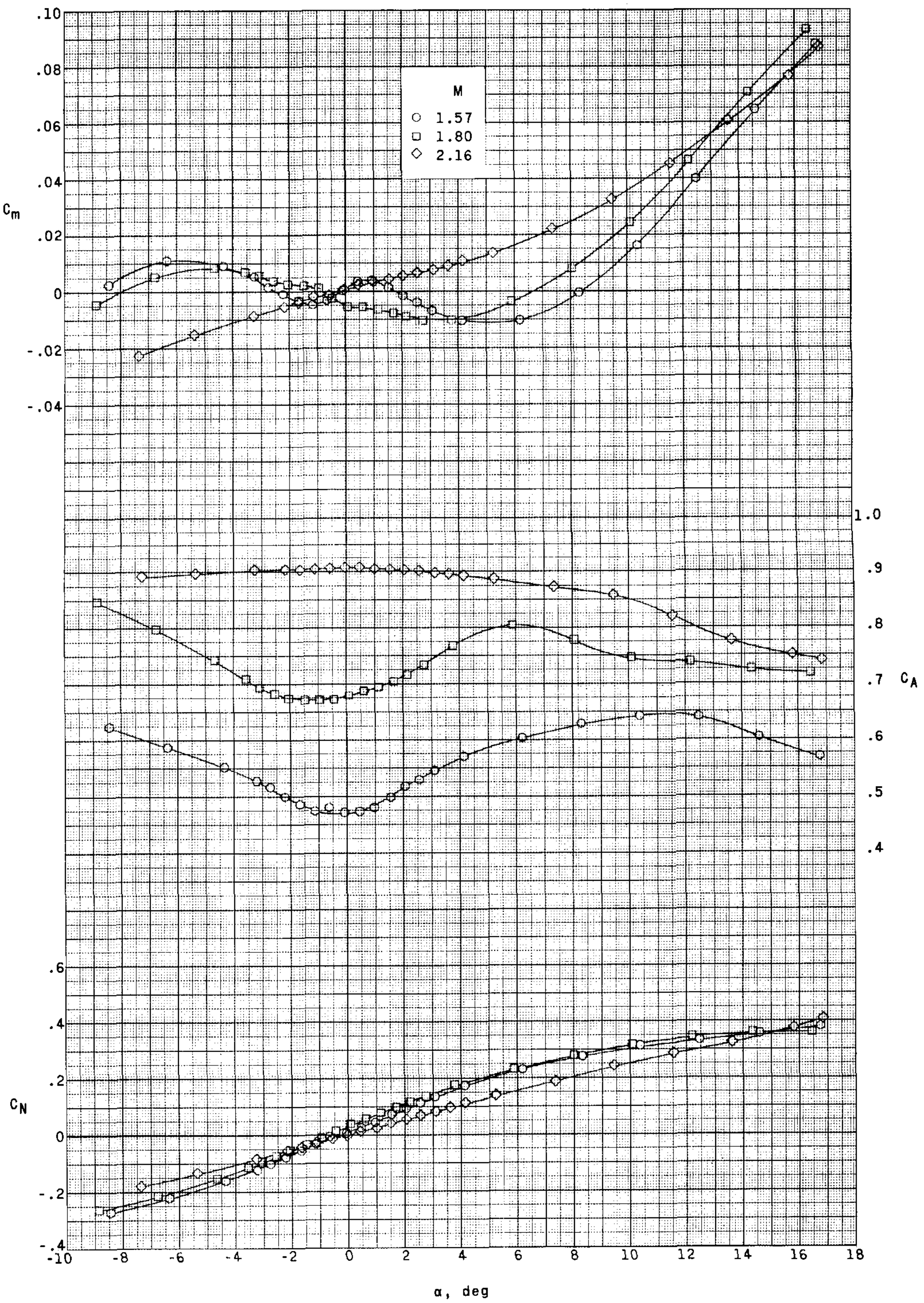


(b) Tripod tower.

Figure 5.- Continued.



(c) Solid tower and nozzle fairing.

Figure 5.- Continued.

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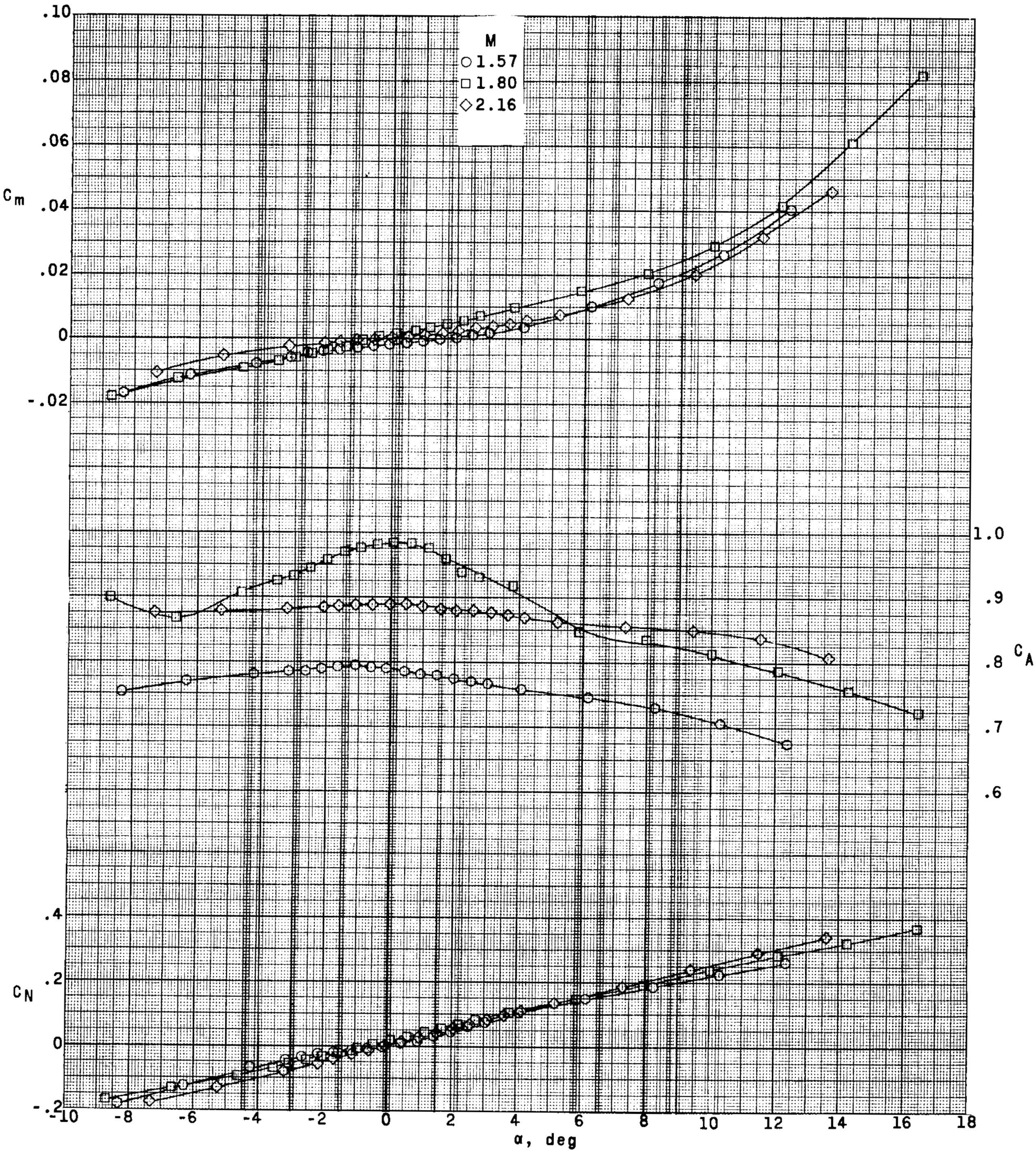
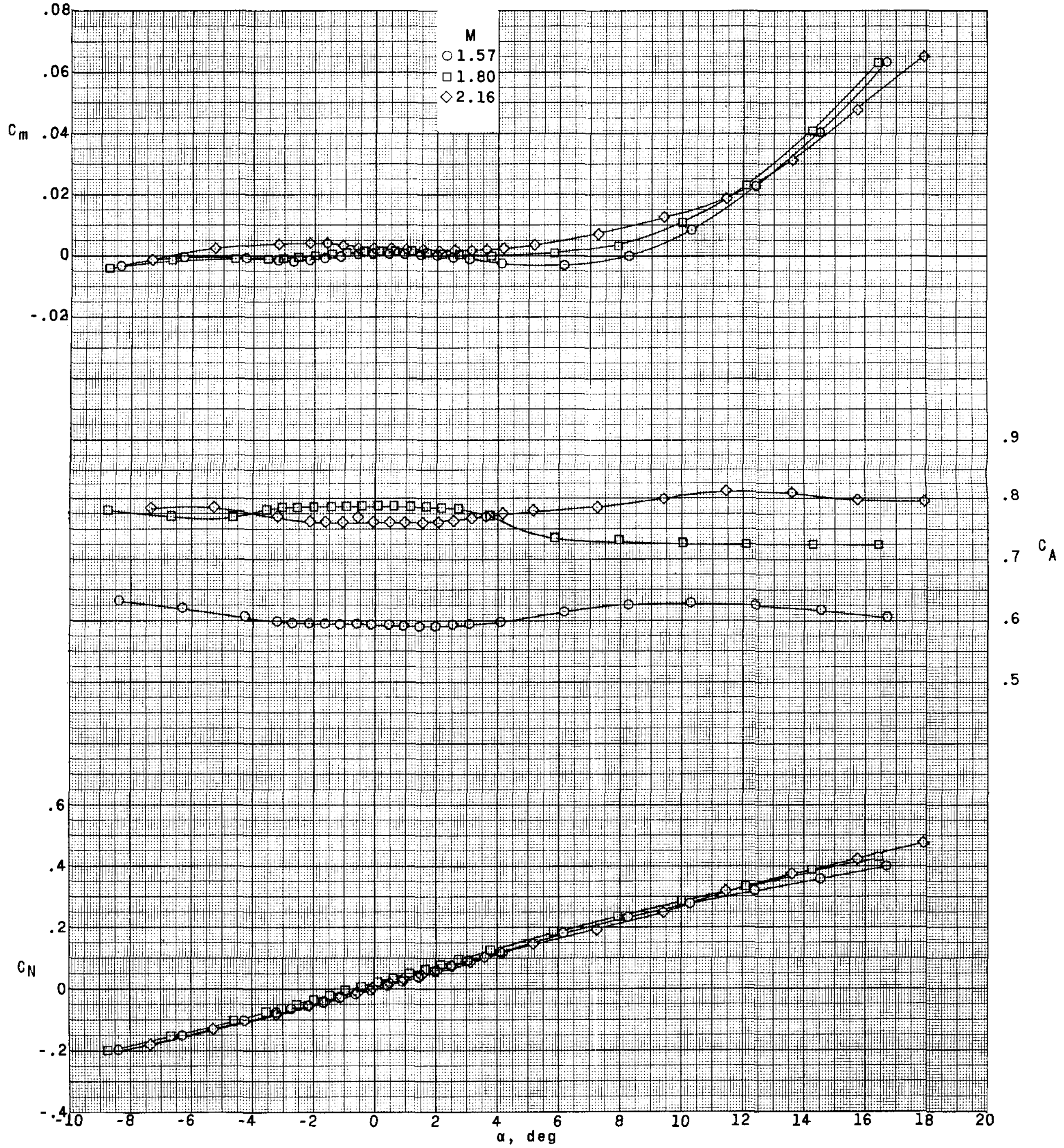


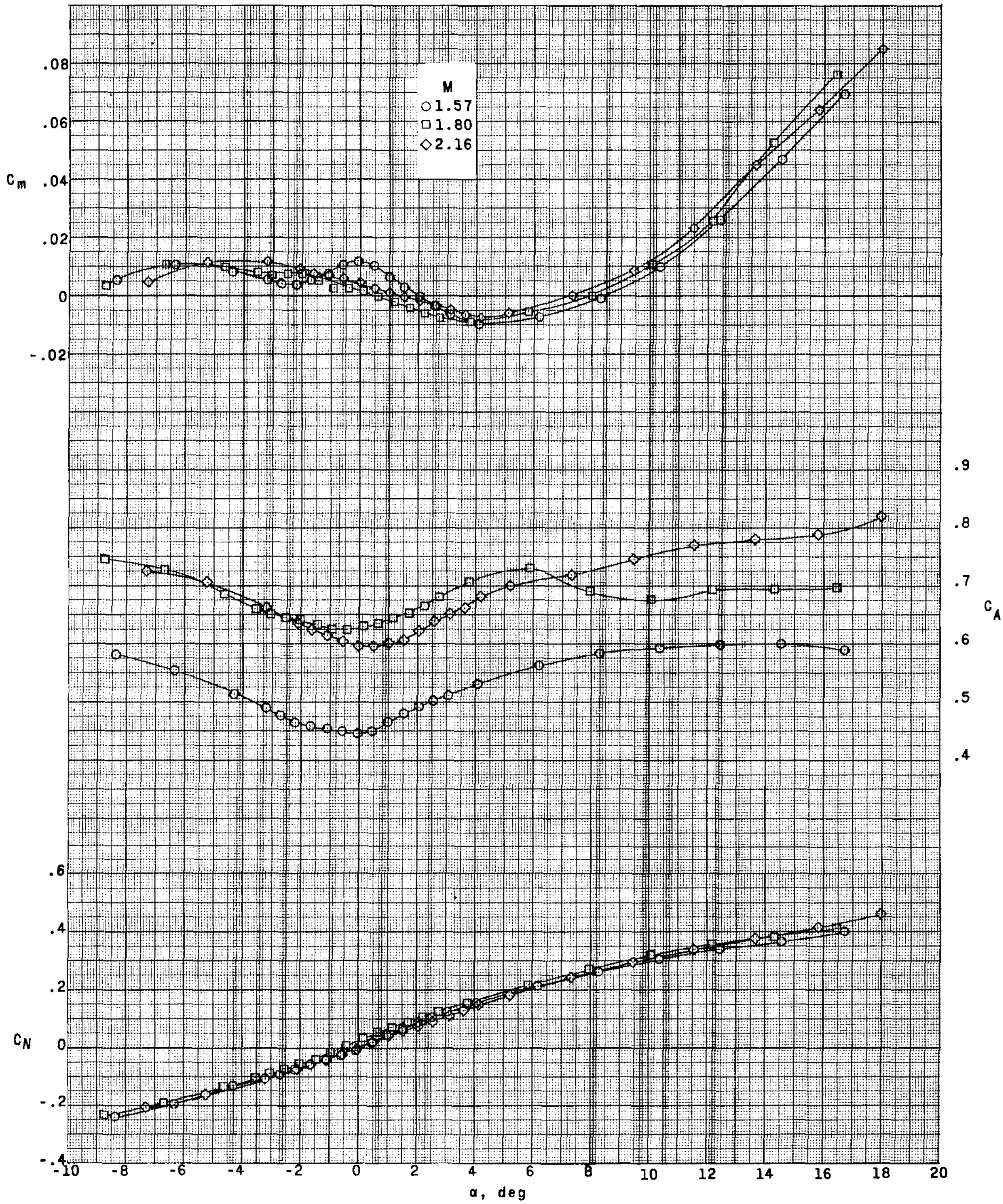
(d) Solid tower.

Figure 5.- Continued.



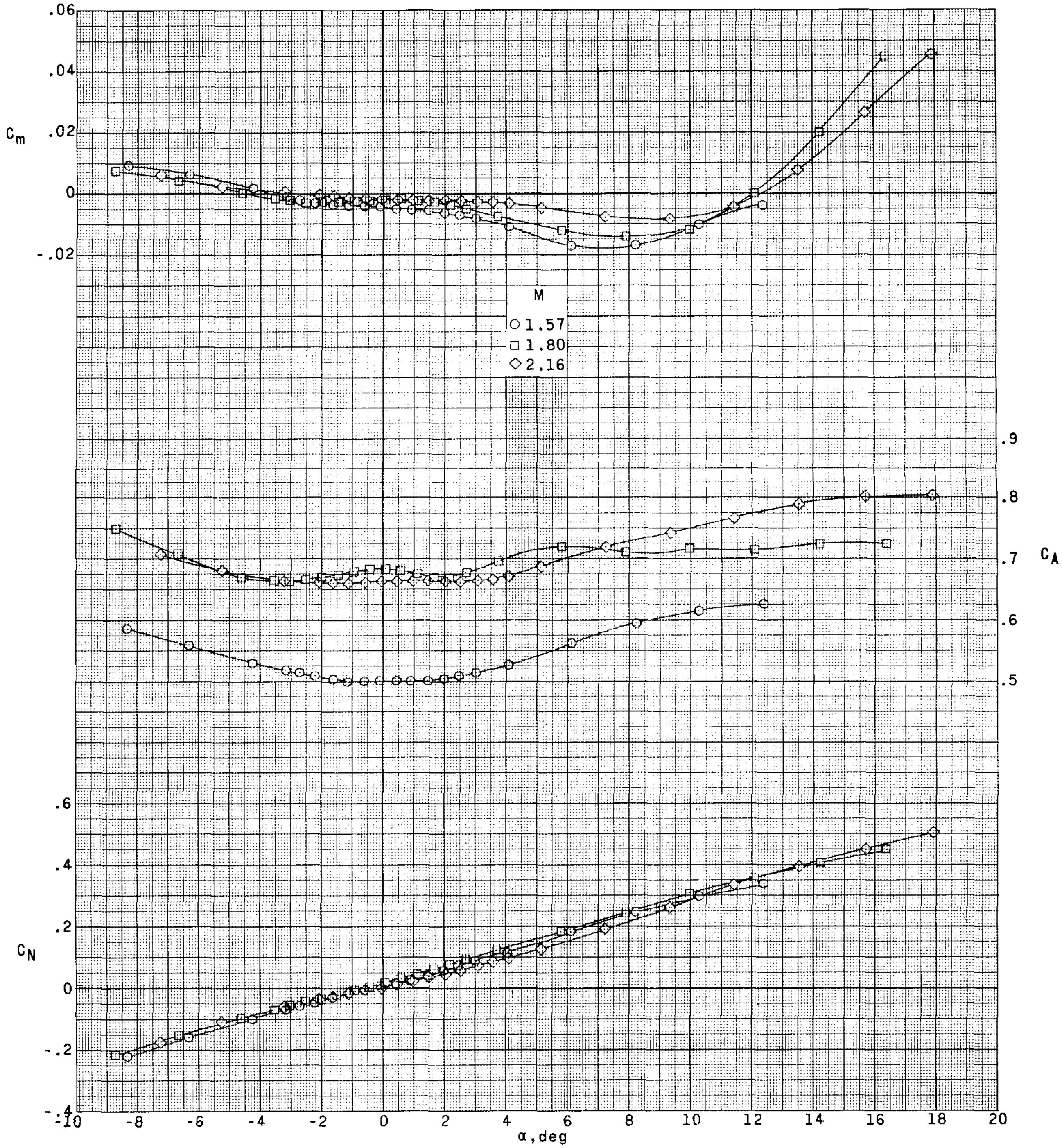
(e) Tripod tower and two stabilizing rings.

Figure 5.- Continued.



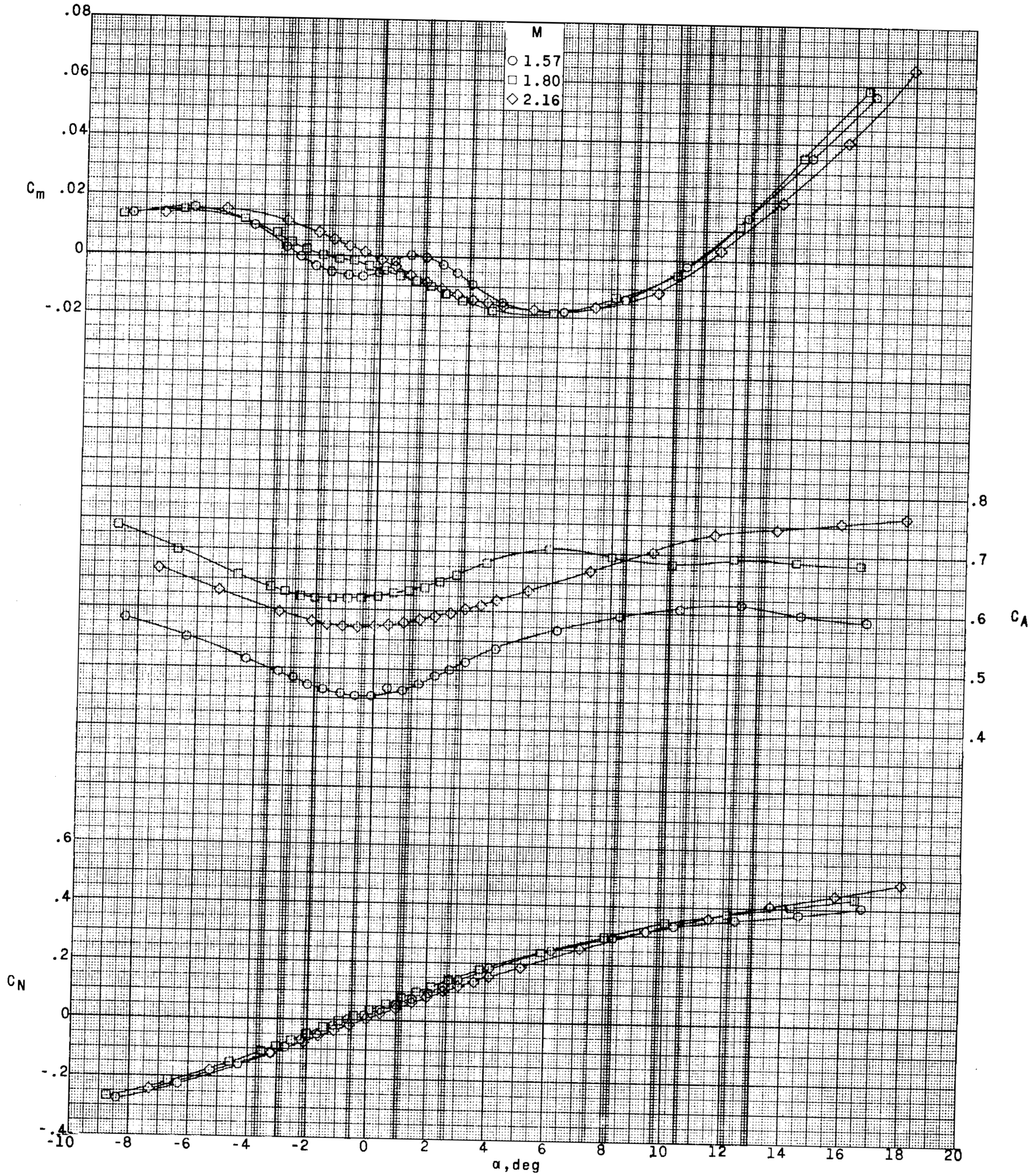
(f) Tripod tower, two stabilizing rings, and nozzle fairing.

Figure 5.- Continued.



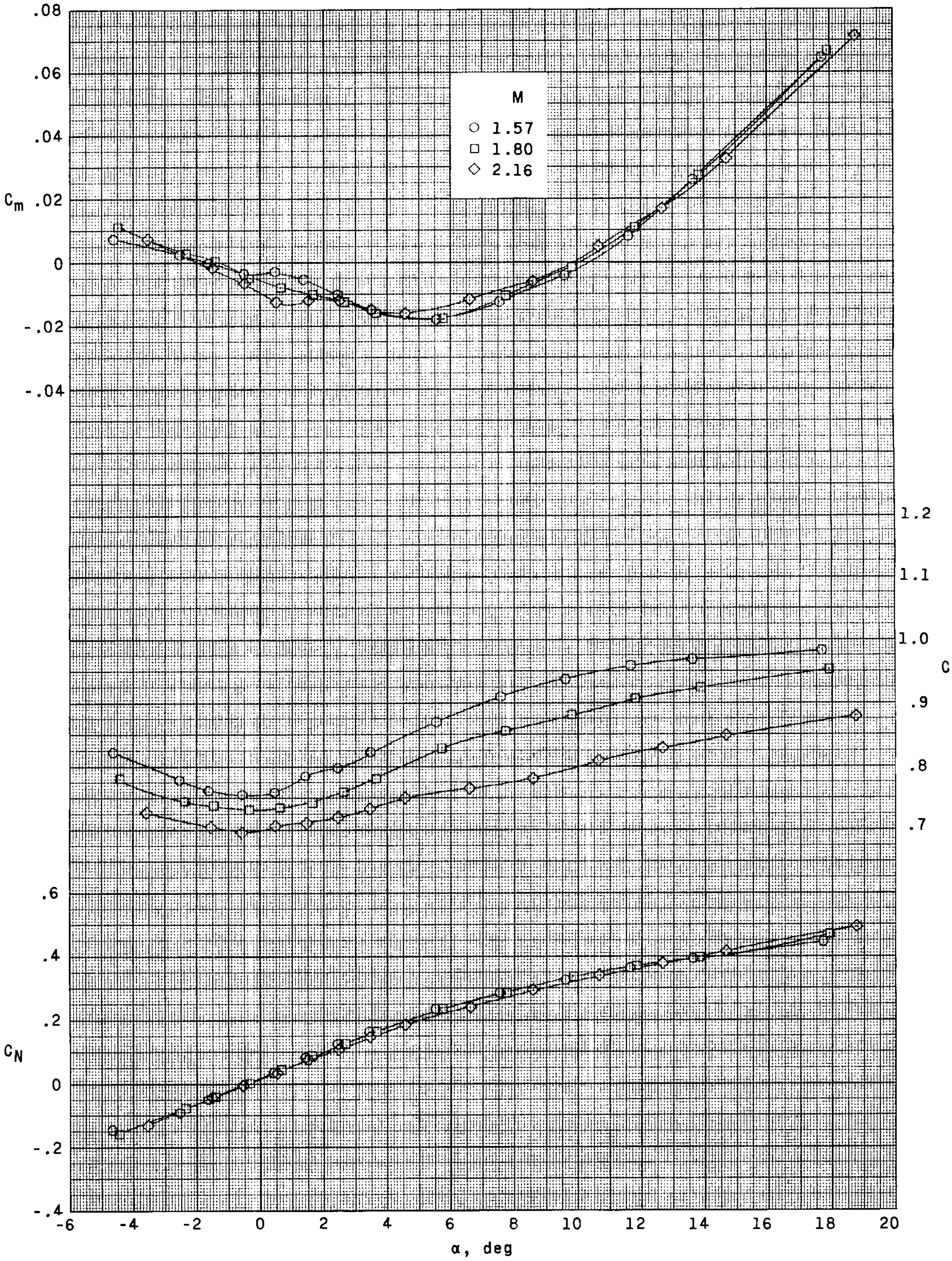
(g) Tripod tower and three stabilizing rings.

Figure 5.- Continued.



(h) Tripod tower, three stabilizing rings, and nozzle fairing.

Figure 5.- Continued.



(i) Four-legged tower and nozzle fairing.

Figure 5.- Concluded.

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